The Birefringence Change of Optical Fiber Polarizer with Fe Film in Corrosive Solution

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BACKGROUND - Requirement

Corrosion of metallic structures → Severe damages

How to monitor Corrosion
**BACKGROUND - Optical fiber sensor**

- **Bare fiber type (grating) sensors**

  ![Bare fiber type](image1)
  ![Bare grating type](image2)

  **deficiency**: Vulnerable to the interference of external stress, optical fiber (grating) being easy to fracture and low accuracy of sensor.

- **Corrosion of sensitive membrane type sensor**

  ![Sensitive membrane type optical fiber](image3)
  ![Sensitive membrane type optical grating](image4)

  **deficiency**: Sensor sensing features have low repetition rate, corrosion sensitive membrane is easy to fall off, idea of designing experiment is singleness, Encapsulation is difficult.
**BACKGROUND - Mechanism**

- A single mode optical fiber is side-polished to obtain a D-shaped optical fiber. D-shaped optical fiber is coated with Fe film to obtain **polarization mode**.

- D-shaped optical fiber is used to monitor the corrosion of Fe film.

![Diagram](image)

Before Corrosion

After Corrosion

Chemical changes → Physical changes
SIMULATION - Methods

- Electromagnetic Waves, Frequency Domain is used as physics interfaces.
- Mode analysis is used to study the simulation.
- The scattering boundary condition is used to reduce the reflection from the boundary.

Fig1. geometric graph of simulation
**SIMULATION - Equations**

**Power**

\[ I = \int J \cdot dS \]

\[ P = I^2 R \]

**Leakage Power**

\[ \eta(\text{dB}) = 10 \log \left( \frac{P_{\text{Leakage}}}{P_{\text{Total}}} \right) = 10 \log \left( \frac{I_{\text{Leakage}}^2}{I_{\text{Total}}^2} \right) \]

**Extinction Ratio**

\[ \text{ER(\text{dB})} = 10 \log \left( \frac{P_{\text{TE}}}{P_{\text{TM}}} \right) = 10 \log \left( \frac{I_{\text{TE}}^2}{I_{\text{TM}}^2} \right) \]
SIMULATION – Two models

Fig 2. D-shaped optical fiber **without** Fe film

Model A

Fig 3. D-shaped optical fiber **with** Fe film

Model B

**With Fe film**

**Without Fe film**
SIMULATION - Power Leakage

\[ \eta(\text{dB}) = 10 \log \left( \frac{P_{\text{Leakage}}}{P_{\text{Total}}} \right) = 10 \log \left( \frac{I_{\text{Leakage}}^2}{I_{\text{Total}}^2} \right) \]

Red—\( P_{\text{total}} \)  Blue—\( P_{\text{Leakage}} \)

Model A

Leakage power vs Polishing depth
**SIMULATION - ER value**

\[
ER(\text{dB}) = 10 \log \frac{P_{TE}}{P_{TM}} = 10 \log \frac{I_{TE}^2}{I_{TM}^2}
\]

**Model B**

![Graph showing ER value vs thickness of Fe film](image)

- In Air
- In NaCl
SIMULATION – Corrosion process

Fe $\rightarrow$ Fe$_3$O$_4$ $\rightarrow$ Fe$_2$O$_3$ $\rightarrow$ NaCl

(a) Intact stage  |  Eroded stage  |  Final stage

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<th>$n_{\text{Real}}$</th>
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<td>NaCl</td>
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(b) ER (dB)  | Leakage (dB)  

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<tr>
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<th>ER in air</th>
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CONCLUSIONS

- D-shaped optical fiber can be coated with Fe film to obtain polarization mode.
- With the increasing of side-polished depth, leakage power will decrease.
- With the increasing of the Fe-film’s thickness, ER value will decrease.
- With the corrosion of Fe-film, ER value will decrease.
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